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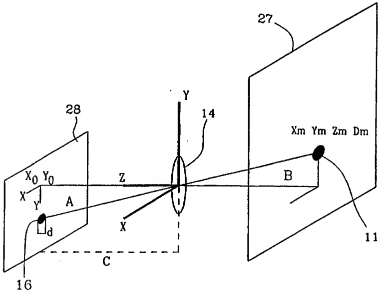


(57) Abstract

A method for determining position (X_m, Y_m, Z_m) of a body (12) provided with at least one marker object (11) with a known dimension parameter (D_m), by means of at least one camera unit (10), provided with a sensor device (15) and an optical element (14) in a determinable distance (c) from said sensor device (15), and means for retrieving and calculation (22). The method comprising steps of: computing the coordinates (x_p, y_p) of an image (16) of said object (11) reproduced on said sensor device (15), computing a dimension parameter (d) of said object (11) corresponding to said provided dimension parameter (D_m), calculating the proportion of parameters obtained to determine the position (X_m, Y_m, Z_m) of said object (11).

METHOD AND ARRANGEMENT FOR DETERMINING THE POSITION OF AN OBJECT

TECHNICAL FIELD OF THE INVENTION

The present invention relates to a method and arrangement for determining position of a body provided with at least one marker object with a known dimension parameter, by means of at least one camera unit, provided with a sensor device and an optical element in a determinable distance from said sensor device, and means for retrieving and calculation.

BACKGROUND AND RELATED ART

Motion analysis is now a well-known method using camera unit and computer aid to analyse, e.g. biomechanichs of human, animals or motions of a robot arm etc.

In a simple system markers are attached to the object to be analysed. In the past the object provided with the markers was first filmed and then manually analysed and digitalised to determine the correct position of the markers. This was a time-consuming procedure.

Presently, cameras equipped with so-called CCD plates are used. CCD plate, which is a light sensor, is generally arranged in communication with necessary optical elements. A CCD plate, consisting of lines of charged coupled sensors arranged as a matrix, i.e. arranged in an X and Y coordinate system, for one or several colours, converts the light (from the optical element) projected on it, by electronically scanning in Y direction each line of X sensors and producing a television (video) signal. Then, the signals may be analysed in different ways to detect the position of the markers attached to the object.

Presently, two or more camera units are used to measure the distance to an object.

SUMMARY OF THE INVENTION

It is an object of the present invention to present a method and device to accurately determine the position, preferably the three dimensional position of an object using at least one camera unit, substantially in real time.

These objects are achieved by using a method, comprising steps of:
- computing the coordinates of an image of said object reproduced on said sensor device,
- computing a dimension parameter of said object corresponding to said provided dimension parameter,
- calculating the proportion of parameters obtained to determine the position of said object.

The invention also concerns an arrangement for determining the position of a body provided with an object having a known dimension parameter to said body, said system comprising at least one camera unit, including a sensor device and an optical element, in a determinable distance from said sensor device, and means for retrieving and calculation, which is arranged to compute the coordinates of an image of said object reproduced on said sensor device, compute a dimension parameter of said object corresponding to said provided dimension parameter, calculate the proportion of parameters obtained to determine the position of said object and means for presenting the determined position.

Other advantageous embodiment according to the present invention are characterised in depending claims.

BRIEF DESCRIPTION OF THE DRAWINGS

In the following the invention will be described with reference to enclosed drawings, in, which:

Fig. 1 is a schematic diagram of a simple motion analyse system according to the invention.

according to fig. 1.

Fig. 3 is a schematic section through a digitalised marker according to the present invention.

Fig. 4 schematically illustrates the principle of the present invention.

BASIC THEORY

Basically, an analogous system uses a conventional video signal from a camera as an input. By means of said signal the X and Y coordinates for the marker, which separate from the surroundings in intensity of light are calculated. The aim is to measure a movement of the marker as exact as possible, i.e. the inaccuracy, which is a result of the video signal consisting of a set of finite number of dots to be minimised.

The video signal consists of a number of lines, which are scanned in chronological order. A marker generates an image, which extends over one or several lines. By means of a comparator, it is possible to determine the start and the end of a marker section on a line may be determined. The marker image on a line is called a segment. The time is measured partly from the beginning of the line to the beginning of the segment (X_s) and partly from the beginning of the line to the end of the segment (X_e). The mean value of these two periods is a measure for the position of a segment in the space, in horizontal direction (if the lines are horizontal) while the serial number of the line (S) is a measure for position of the segment in the vertical direction. The length *l* of the segments is then X_e-X_s.

The X and Y coordinates of the marker, X_m and Y_m, respectively are obtained through formulas 1 and 2:

$$X_m = \frac{\sum \frac{(X_e-X_s)\cdot(X_e+X_s)}{2}}{\sum (x_e-X_s)} \qquad (1)$$

$$Y_m = \frac{\sum((X_e - X_s) \cdot S)}{\sum(x_e - X_s)} \qquad (2)$$

The $\sum$ sign indicates that the summation is carried out over all segments being a member of the marker image.

The above is applicable for an analogous signal. Similar calculations may be carried out, if image dots from a digital detector are transferred to another order than linear, where the centre points for all image elements that are members of the same marker are calculated. First, the image elements can be translated to lines and then the calculation may be carried out as in the analogous case.

The times X_s and X_e can be measured with an electronic counting device connected to an oscillator, which also controls the video signal. The counter starts in the beginning av the line and it is read when the start and end of a segment are reached. One problem is that the oscillator frequency, due to technical and economical reasons is limited. In the digital case the problem may be that the image elements cannot be as small as required.

To overcome this problem in analogues case, a comparator is provided, which starts an integrator, which generates a linear potential slope, which starts from a potential V_a to V_b at time X_s. The slope is than sampled and measured when the counter changes between two values. The point when the slope passes a predetermined alteration value is used to define the time X_{ss}. The difference between X_s and X_{ss} is a constant and it is determined by the integrator and the delays in the comparators. The time X_{ss} is easily calculated from the measured points on the potential slope at the time for the change of the counter provided that at least two points on the slope are measured. For example, if two voltage values are measured, V_1 at t_1 and V_2 at t_2 and V_0 is between V_1 and

V_2, X_{ss} is interpolated by formula 3:

$$X_{ss} = t_1 + \frac{(t_2-t_1).(V_0-V_1)}{V_2-V_1} \quad (3)$$

The time X_e is measured in same way. In this embodiment a linear slope is used, because the calculations become simpler, however, other curves may be used.

DETAILED DESCRIPTION OF AN EMBODIMENT

A simple schematic system according to the present invention is shown in fig. 1. The system comprises at least one camera 10 directed to a body, in this case a human body 12, to be analysed and at least one marker 11 attached to the body 12.

The camera 12 may be connected to a computer device 13, to further process the received signals from the camera 10.

In the following, references will be made to an embodiment of a system operating in IR region, i.e. the camera "sees" bodies emitting infrared radiation. In a preferred embodiment the marker has a substantially spherical configuration provided with a reflecting surface. The camera 12 may be provided with means to emit IR-light, which is then reflected by the marker. The special design of the marker allows the cameras from different angels apprehend a circular form for a correct positioning.

In this embodiment the camera 10 is equipped with a CCD unit operating substantially in same way as described above. The block diagram of fig. 2 schematically illustrates some primary parts of the camera 12 intended to execute the method according to the invention.

The camera 10 includes optical elements 14 such as lenses and other focusing means (not shown) to projet the image 16 of a marking

device 11 onto a CCD unit 15. The surface of the CCD unit is then scanned and the image signals including pixel information are converted to a suitable video signal by means of a converting unit 17, which may be integrated in the CCD unit. The video signal representing image lines, is then serially or in parallel sent to a processing unit 18. The processing unit digitalises the received video signal, for example using an A/D-converter 19. This signal may also be digitalised in unit 17. The processing unit may be connected to a memory unit, not shown, containing a set of instructions for controlling the processing unit.

In respect of the "Basic Theory" part, herein above, the image elements may be arranged in lines by means of a low-pass filter to provide some continuos signal, which can be processed as the analogous signal. However, in the preferred embodiment each image element is measured individually and from the measured values, a value is interpolated, determining when a threshold T is passed, analogously to the Basic Theory part.

The digitalized signal is then passed over to a comparison unit 20, which interpolates individual sample values about the predetermined threshold value T, also called video level, which may be obtained from a memory unit 21. As described above, the object is to determine when the amplitude of the signal passes the value T. Each passage presents a start and stop coordinate of each segment with a high resolution, which can be about 30 x number of pixels on a row. In a computation unit 22 following calculation is executed:

$$X_{high\ resulotion} = Pixel\ No. + \frac{T-V_1}{V_2-V_1} \qquad (4)$$

Where V_1 and V_2 are the signal levels of preceding and succeeding pixels, respectively, received from the comparatione unit 21.

The pixel number may be obtained from a counter (not shown).

Depending on the components used, levels V_1 and V_2 may be measured having resolution of 10 bits, the pixel number (MSB) 9 bits and $(T-V_1)/(V_2-V_1)$ 7 bits. Then the centre point x' of the marker is computed in a computation unit 22 by means of previous values stored in a memory unit 23, using formula (5):

$$x' = \frac{\sum (l_k^n \cdot \bar{x}_k)}{\sum l_k^n} \qquad (5)$$

$$y' = \frac{\sum (l_k^n \cdot S)}{\sum l_k^n} \qquad (6)$$

where l_k is the length of the segment k (i.e., $X_{ek}-X_{sk}$), according to fig. 5,
S is the serial number of the image element, and
x_k is the centre of the segment k.

In the digital case, the formulas (1) and (2) are substituted by formulas (5) and (6), respectively. However, formula (1) and (2) alone do not contribute to obtaining an exact value as desired. To obtain a more accurate, stable and high resolutive x', the n power of l_k is calculated. In the preferred embodiment the square of l_k, i.e. n=2 is calculated.

Fig. 3 schematically illustrates the digitalized two dimensional image 26 of the marker.

The l_k's may then be stored in the memory unit 23, for further calculations. For a circular marker, the area A of the image is calculated using formula $A \approx \sum l_k$. It is also possible to calculate the radius using $A=r^2.\pi$, which yields formula (7):

$$r = \sqrt{\frac{\sum l_k}{\pi}} \qquad (7),$$

which may be computed in the computation unit 22.

Referring now to Fig. 4, which schematically illustrates the fundamental principle of the present invention, the position of the object 11 may be calculated according to the following.

Following are known data:

- x' the centre of the marker image 26 on the detector plane 28, i.e. on the CCD plate 15, computed using formula 5;
- c the distance c from the detector plane 28 to the lens 14;
- X_0, Y_0 the centre of the detector plane, corresponding to the centre of the lens, which are camera constants;
- D_m the diameter of the marker 11.

In the calculation unit 22 following parameters are calculated:

- x_p X_0-x', i.e. the X-coordinate of the marker image on the detector plane relative the centre of the detector plane;
- y_p Y_0-y', i.e. the X-coordinate of the marker image on the detector plane relative the centre of the detector plane; and
- d r x 2, r being the radius as above.

As between the triangle B and the triangle A in Fig. 4, similarity exists, following proportional relationship also exist: $X_m/x_p = Y_m/y_p = Z_m/c = D_m/d$, which enables following calculations in the unit 22:

$$X_m = \frac{D_m}{d} . x_p \qquad (8)$$

$$Y_m = \frac{D_m}{d} . y_p \qquad (9)$$

$$Z_m = \frac{D_m}{d} . c \qquad (10)$$

Where X_m, Y_m and Z_m are the three-dimensional position (vector components) of the marker, and specially the distance between the camera (lens) and the object (11) is

$$Dist = \sqrt{X_m^2 + Y_m^2 + Z_m^2} \qquad (11).$$

It is obvious that the distance c must be determined exactly as said distance varies when focusing, i.e. when said lens is displaced.

The results may then be transformed to an interface unit to further transmission to the computer unit 13, in which the computed values, can be used to show the position of the marker on a screen for simulation, positioning and other applications.

Although, we have described and shown a preferred embodiment, the invention is not limited to said embodiment, variations and modifications may be made within the scope of the attached claims. The processing unit 18 may be integrated in the camera 10, or in a peripheral unit. The number of units and their function in the processing unit 18 may also vary.

Further, the form of the marker may vary due to the application area. Moreover, the system according to the invention may be used to detect distances in other areas, for example in mobile units such as vehicles, aeroplanes etc.

LIST OF DESIGNATION SIGNS

10 Camera unit
11 Marker
12 Body
13 Computer
14 Lens
15 CCD unit
16 Image
17 Converting unit
18 Processing unit
19 A/D-converting unit
20 Comparator
21 Memory unit
22 Calculation unit
23 Memory unit
24 Interface unit
25 Marker
26 Marker image
27 Measurement plane
28 Detector plane

CLAIMS

1. A method for determining position (X_m, Y_m, Z_m) of a body (12) provided with at least one marker object (11) with a known dimension parameter (D_m), by means of at least one camera unit (10), provided with a sensor device (15) and an optical element (14) in a determinable distance (c) from said sensor device (15), and means for retrieving and calculation (22),
the method comprising steps of:
- computing the coordinates (x_p, y_p) of an image (16) of said object (11) reproduced on said sensor device (15),
- computing a dimension parameter (d) of said object (11) corresponding to said provided dimension parameter (D_m),
- calculating the proportion of parameters obtained to determine the position (X_m, Y_m, Z_m) of said object (11).

2. A method according to claim 1,
characterised in,
that the distance (Z_m) to said object is determined using the proportionality between the distance (Z_m) to said object and distance (c) between the optical element and sensor plane, and dimension parameter (d) of the image (16) of the object on said sensor device (15) and the dimension parameter (D_m) of the object.

3. A method according to claim 1,
characterised in,
that the centre coordinate (x_p, y_p) of said image is the distance between a centre point (x', y') of the image and a centre point (X_0, Y_0) on said sensor device.

4. A method according to claim 3,
characterised in,
that centre (x', y') of said of said image on said sensor device

(15) is calculated using steps of

- interpolating a signal form the sensor device containing pixel data for said reproduced image (16) and calculating a centre ($\bar{x}_k$) for a length (l_k) of a segment representing a section of said image, and

- using said calculated centre ($\bar{x}_k$) and said length (l_k) to determine the centroid coordinate (x') by using following formula:

$$\dot{y} = \frac{\sum (l_k^n \cdot S)}{\sum l_k^n},$$

$$\dot{x} = \frac{\sum (l_k^n \cdot \bar{x}_k)}{\sum l_k^n}.$$

5. A method according to claim 3, characterised in, that said start or end point (x_k) is calculated using following formula:

$$X_k = p_m + \frac{T - V_1}{V_2 - V_1}$$

Where T is a predetermined threshold value

V_1 and V_2 are signal levels of preceding and succeeding pixels, respectively

and p is the number of the pixel m.

6. A method according to claim 1 or 2, characterised in, steps of:

- interpolating signal containing pixel data for said reproduced image (16) and calculating a length (l_k) of a segment representing a section of said image, and

- using said calculated length (l_k) to determine the area (A)of the image by using $A = \sum l_k$.

7. A method according to any one of claims 1 to 6, characterised in, that said marking object (11) is substantially spherical.

8. A method according to any one of claims 1 to 7, characterised in, that said known dimension parameter (D_m) is the diameter of said object (11).

9. An arrangement for determining the position (X_m, Y_m, Z_m) of a body (12) provided with an object (11) having a known dimension parameter (D_m) to said body (12), said system comprising at least one camera unit (10), including a sensor device (15) and an optical element (14), in a determinable distance (c) from said sensor device (15), and means for retrieving and calculation (22), which is arranged to compute the coordinates (x_p, y_p) of an image (16) of said object (11) reproduced on said sensor device (15), compute a dimension parameter (d) of said object (11) corresponding to said provided dimension parameter (D_m), calculate the proportion of parameters obtained to determine the position (X_m, Y_m, Z_m) of said object (11) and means for presenting the determined position.

10. An arrangement according to claim 9, further comprising:

means (15) for collecting image data for said body,

converting means (19) for producing a digital signal containing pixel data for said reproduced image (16),

comparator unit (20) for generating difference between a pixel signal level and a threshold value (T),

computation unit (22) for calculating a centre point ($\bar{x}_k$) for length (l_k) of each segment representing a section of said

image, calculating a centroid coordinate (x') and/or an area of said image and/or a radius of said image.

11. An arrangement according to any one of claims 9 or 10, characterised in,
that said sensor device (15) is a CCD plate.

FIG.1

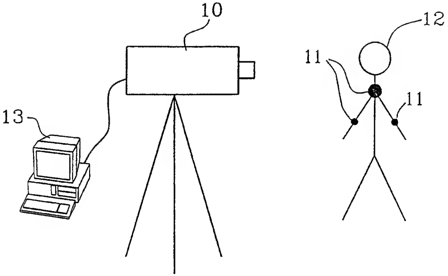


FIG.2

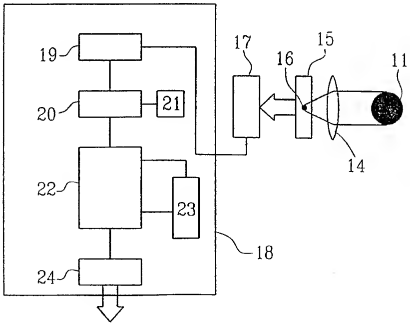


FIG.3

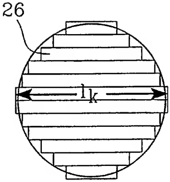
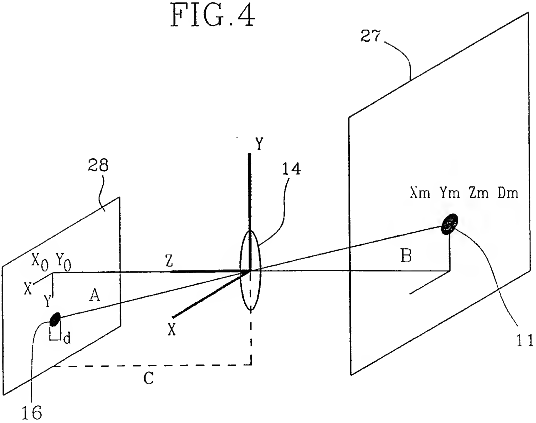


FIG.4



INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 98/00033

A. CLASSIFICATION OF SUBJECT MATTER

IPC6: G06T 7/00, A61B 5/103
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC6: A61B, G06F, G06T, H04N

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

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C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5459793 A (S.NAOI ET AL.), 17 October 1995 (17.10.95), abstract --	1-11
A	US 5072294 A (G.L.ENGLE), 10 December 1991 (10.12.91), abstract --	1-11
A	US 5231674 A (D.CLEVELAND ET AL), 27 July 1993 (27.07.93), figure 4 -- --------	1-11

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
1 April 1998	20 -04- 1998
Name and mailing address of the ISA/ Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Authorized officer Malin Keijser Telephone No. +46 8 782 25 00

INTERNATIONAL SEARCH REPORT

Information on patent family members

02/03/98

International application No.
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